Physiological Evaluation of Air-Fed Ensembles

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Background

- Air-fed ensembles, encapsulating suits with an external source of breathing air which provides respiratory protection without the use of a tight-fitting facepiece (Figure 1), are currently being worn by workers in the nuclear, chemical, biohazard, and pharmaceutical industries.

Figure 1. Typical air-fed ensemble. Photos courtesy of Jim Gathaney, CDC.

- The National Institute for Occupational Safety and Health (NIOSH) has proposed a concept for a certification module for air-fed ensembles, which will include an evaluation of inhaled O_2 and CO_2 concentrations during human testing; however, recent research including human subject testing of currently available air-fed ensembles is lacking.(1)
- Preliminary testing of one ensemble on the NIOSH Automated Breathing and Metabolic Simulator (ABMS) has demonstrated inhaled O_2 and CO_2 concentrations that might be of concern during normal use (Figure 2). Results of one ABMS test in which oxygen consumption (VO_2) varies from 0.5 L/min to 2.0 L/min are shown in Table 1. During the 2.0 L/min workload, which is considered moderate intensity exercise, average inhaled CO_2 and average inhaled O_2 exceeded the failure criteria for these variables (>1.0% and <19.5%, respectively, for a four-hour open-circuit respirator).(2)

Figure 2. Automated Breathing and Metabolic Simulator (ABMS) testing of an air-fed ensemble.

Table 1. Results of ABMS testing of an air-fed ensemble.

VO_2	$FICO_2$min	$FICO_2$ave	FIO_2ave
0.5 L/min	0.1%	0.5%	20.5%
1.0 L/min	0.3%	0.8%	20.3%
1.5 L/min	0.6%	1.5%	19.8%
2.0 L/min	1.0%	2.4%	18.9%

Objective

The purpose of this laboratory-based research project is to evaluate the respiratory stresses experienced by men and women wearers of commercially available air-fed ensembles at rest and during low-intensity exercise on a treadmill. The objective of this research project is to provide the potential test methods for the human-subject certification testing of air-fed ensembles to the Policy and Standards Development Branch, NPPTL, for incorporation into a draft certification module for air-fed ensembles. In addition, the human data consisting of measured inhaled gas concentrations, pressures, and temperatures will inform the process of setting realistic pass/fail criteria for these variables. Ultimately, completion of the objectives of this project will result in a significant step toward ensuring that air-fed ensembles perform safely.

Proposed Methods

Nuclear, hazmat, chemical, and pharmaceutical workers between the ages of 18 and 41 will be recruited for the study from the Pittsburgh area In order to quantify the oxygen consumption, carbon dioxide production, heart rate, minute ventilation and peak flow elicited by the resting, low intensity, and moderate intensity trials of treadmill walking, baseline testing will be conducted. This testing will consist of standing rest for 6 minutes, treadmill walking at 2.75 mph, 0% grade (~ 3 METS) for 6 minutes, and treadmill walking at 3.5 mph, 5% grade (~6 METS) for 6 minutes. Subjects will then don one of three different air-fed ensembles in a random order and repeat the rest and exercise bouts. Descriptive statistics will be used to determine mean inhaled O_2 and CO_2 concentrations and inhalation and exhalation pressures and temperatures. Comparisons of independent variables will be made using repeated measures analysis of variance. In addition, further testing using the NIOSH ABMS may be conducted for comparison with results from other air-supplied respirators.(3)

Variables to be Measured and Ensembles to be Tested:

1) Metabolic and Respiratory Variables (O_2 consumption, minute ventilation, inhalation flow rate and breathing frequency, during baseline testing)
2) Heart Rate and Oxygen Saturation
3) Inhaled Gas Temperature
4) Inhaled Gas Concentrations
5) Inhaled and Exhaled Pressures
6) Air-Fed Ensembles
   a. Bullard two-piece (parka and suit) PC90 airline respirator
   b. Indutex SprayGuard Airfed Suit
   c. Sperian BP ventilated suit

Expected Outputs and Outcomes

- Presentation at national and stakeholders meetings
- Peer-reviewed journal publication
- Data from the study is used to support development of a draft certification module for air-fed ensembles by the Policy and Standards Development Branch, NPPTL
- Publication referenced in published draft standard module

Timeline

- FY10 (Oct 2009 – Sept 2010)
  - Develop protocol and complete external peer-review and NIOSH HSRB approval (June 2010)
  - Complete hardware/software system for data acquisition (June 2010)
  - Complete testing of 15 men, 15 women (September 2010)
- FY11 (Oct 2010 – Sept 2011)
  - Complete data analysis and submit abstract to national meeting (November 2010)
  - Present all findings to the Policy and Standards Development Branch, NPPTL (November 2010)
  - Complete draft manuscript (Sept 2011)

References

1. Poirier, L.: An Evaluation of an Air-Supplied Blouse and an Air Hood. *Am Ind Hyg Assoc J. 60*:116 – 119 (1999).
2. Code of Federal Regulations, Title 42, Part 84, Washington, D.C.:USGPO (2004).
3. Sinkule, E., N. Turner, and S. Hota. Automated Breathing and Metabolic Simulator (ABMS) CO2 test for powered and non-powered air-purifying respirators, airline respirators, and gas masks. *Am Ind Hyg Assoc J.* , #227, Dallas, TX, p. 54.

Disclaimer

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